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DESIGN MANUAL FOR THE VECTOR GENERAL GRAPHICS DISPLAY UNIT

by

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This report describes the program description of an interactive graphics package interfacing the Vector General Graphics Display Unit and a Digital Equipment Corporation PDP-11/50 computer. The program was written in the C-programming language and designed to be used in the multiprogramming environment of the UNIX Timesharing operating system. Included is a description of the Vector General, operating system modifications, device driver, and interface routines.

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ABSTRACT

This report describes the program description of an interactive graphics package interfacing the Vector General Graphics Display Unit and a Digital Equipment Corporation PDP-11/50 computer. The program was written in the C-programming language and designed to be used in the multiprogramming environment of the UNIX Timesharing operating system. Included is a description of the Vector General, operating system modifications, device driver, and interface routines.

TABLE OF CONTENTS

I. INTRODUCTION

This manual is the program description for an interactive graphics package interfacing a Vector General Graphics Display System and a PDP-11/50 user. The Vector General Graphics Display System (vector general) is an interactive graphics cathode ray tube (CRT) display that is connected to the PDP-11/50 computer via a modified DR11-B interface. The display interacts with an on-line user by displaying pictorial information on the surface of the cathode ray tube and by accepting inputs from external control devices. The inputs are requested and processed by computer programs that alter and maintain the output picture being presented to the user.

This manual assumes that the reader is familiar with the C-programming language and the UNIX operating system. The terminology used herein without explanation refers to the features and registers in the display unit. A more detailed description can be found in the Vector General Graphics Display Unit Reference Manual (VG 101056). A user's manual is published separately.

The software design can be divided into five major categories:

1. Modifications to UNIX
2. System Routines

3. Memory Allocation

4. User Interrupt Routines

5. User Interface Routines

The remaining sections of this manual describe these divisions. References are repeatedly made to object lists, object buffer lists, and element lists. These formats can be found in Appendix A. Many external global variables are used by the various display routines. These variables are described in Appendix B. The many "defines" are detailed in Appendix C.

The general design for the display software is such that all routines, defines, and external names (UNIX modifications and system routines excluded) are archived in a system library, /lib/libv.a. The user can then include this file at compile time and have access to the entire display software for his use. As a result, the convention has been adopted that all routines and global variables begin with "vg". This avoids collision of name definition if the user avoids names starting with "vg".

II. MODIFICATIONS TO UNIX

The memory allocation scheme of UNIX had to be modified to permit the Vector General Graphics Display System to access the display list. A real-time system call,

rtime(), has been added to make the calling process real-time by relocating the process contiguously within a thirty-two thousand three hundred sixty-eight byte memory block. The memory allocation of the process is not allowed to cross a memory address that is a multiple of thirty-two thousand three hundred sixty-eight. This allows the vector general display to programmatically address any of the thirty-two thousand three hundred sixty-eight memory addresses without resetting the extended memory bits. The rtime() call also sets the process priority so that the operating system will not swap the process onto the disk. This locks the process into a fixed memory area. The real-time process can then dynamically modify the display list while the vector general is continuously accessing the same display list via its direct memory access channel.

Because of the requirement to lock a real-time process into a fixed memory area, the operating system permits only a limited number of simultaneous real-time processes. If the required memory area is allocated to another non-swapable process or the maximum number of real-time processes has been previously allocated, the requested process is not made real-time and an error is returned to the caller.

III. SYSTEM ROUTINES

The vector general has been divided into six minor devices. This simplifies the communication between the user and the device driver. Each minor device has associated with it a flag that is set in response to the user's open() command. Since the vector general is a dedicated device, any attempt to share the vector general between users or use the vector general without opening all minor devices will result in an error to the caller. After all six minor devices have been opened, a single vector general system flag, vglock, is set. This system lock is checked prior to any read or write operation. In addition the process is made real-time, the user process number is retained in vgproc, and the display is flagged as idle. The user process number is used to pass the vector general interrupts to the user via psignal(). The display idle flag allows the initial display list to start the vector general but prevents subsequent display lists from abnormally terminating a previous display list.

Initialization of user controlled parameters is usually the next requirement. When the user issues a write() command via minor device two, VGCNTRL, the contents of the user's buffer is interpreted as the refresh reference count. This determines the number of vector general frame clock interrupts permitted before reinitialization of the

display list.

The vector general subroutine stack option permits accessing non-contiguous display lists. However, the vector general must have the memory address of any non-contiguous display lists encoded within a contiguous display list. This requires the user to have access to the real PDP-11 memory addresses of his display lists. The mapping of user space to real memory addresses is accomplished by the user's issuance of a write() command followed by a read() command via minor device zero, VG. The write command stores the real PDP-11 memory address of the user buffer in the variable vgaddr. The user's read command passes the value of the real PDP-11 memory address to the user via the passc() routine.

When dynamically modifying display lists, the memory address encoded in a display must often be converted to a user space address for referencing a user's display list. This capability is provided by a read() command using minor device five, VGCNVT. The base block number of the user's process obtained by the vastrategy() routine is passed to the user via passc().

When the user has created the display, he must pass the address of the display list to the vector general. The user's write() command using minor device one, VGDISP, accomplishes this task. The lower sixteen bits of the address are stored in baddrl. The upper two bits are encoded in baddrx. If the display has not been

initialized, the routine vastart() sends the address to the vector general and starts the vector general's operation. If the display has been initialized, the new address in baddr1 represents a new display list to be used after completing the active display list.

The vector general operates independent of the user process after being given a display list. However, communication with the system routines is maintained via interrupts. A frame clock interrupt signal is generated every 8.33 milliseconds and a device interrupt is generated whenever the user operates one of the enabled peripheral devices. The frame clock interrupt increments a counter until the counter equals the refresh reference count. At that time the display is reinitiated by a call to vastart().

The device interrupt handler passes the interrupt to the user via signal number two or fifteen. All device interrupts except the ASCII CNTRL T character are passed to the user via signal fifteen. The ASCII CNTRL T character input via the vector general keyboard is interpreted as a control key terminating the process, causing the display to be cleared, and notifying the user via signal two. Occasionally, the user may desire the CNTRL T character as data. This is provided by input of the ESC character from the vector general keyboard. This results in the next interrupt being sent to the user regardless of the type or content. Each device interrupt also causes

the values of various vector general registers to be extracted and stored in vgbuf[] for transfer to the user.

The transfer of the vector general register values to the user can be accomplished in several different ways. The most common is in response to a device interrupt. The user can acquire the interrupt state of the vector general (except the dial positions) by issuing a read() command using minor device one, VGDISP. The contents of vgbuf[] are passed to the user via the passc() routine. The user's read() command with minor device two, VGCNTRL, will force an update of the vgbuf[] before passing the values to the user. When minor device three, VGFNSW, is used in a read operation, the values of the function switches are updated prior to sending vgbuf[] to the user. VGDIAL, minor device four, extracts the values of the ten dial positions before transmission of vgbuf[]. The vector general dial positions are acquired via a separate read() command because sixteen microseconds are required to read each dial position to the full twelve bit precision.

The vector general's P-bit interrupt is not utilized in this software interface. Therefore, the P-bit interrupt handler is an empty routine.

The source code for the system routines is maintained in /usr/sys/dmr/vgdrvr.c. A copy of vgdrvr.c is included as Appendix D.

IV. MEMORY ALLOCATION

A. FIXED MEMORY ALLOCATION

The user space memory allocation for the vector general registers and the picture display list use an unorthodox technique to obtain sequential memory locations. All the integer variables defined in the file vgreg.h correspond to the named vector general registers. The order of the variables is the order in which the values are read from the vector general. Because the loader assigns variables sequentially, this technique allows the variables to be referenced by incrementing an address pointer without requiring a structure definition.

The file vgsys.h contains a similiar sequence of integer variables used as the display list for initializing the picture parameters. Each integer variable of this file is a vector general command or a vector general data word. The order of the variables cannot be changed without affecting the operation of the vector general.

B. TUNABLE MEMORY ALLOCATION

The arrays and vectors that directly limit the size of the interface data structure are defined in the files vglob.h and vgobj.h. When specific applications require

the interface data structure to be altered, the define statements used to determine all array and vector sizes are located in vadef.h. This permits any of the system parameters to be modified by referencing a single file.

V. USER INTERRUPT ROUTINES

A. INTERRUPT HANDLER (vadpiv)

The basic interrupt handler, vadpiv(), is called in response to signal fifteen from the system device interrupt handler. To determine which vector general device caused the interrupt, vadpiv() obtains the interrupt state of the vector general via the user interface routine vadio(). vadio() transfers the values of eighty-three vector general registers into eighty-three contiguous words of memory starting at the address of vafsl. The value of the priority interrupt request register (PIR) can then be examined to determine the appropriate interrupt handler.

B. KEYBOARD CHARACTER INTERRUPT HANDLER (vgkpiv)

The keyboard character interrupt handler, vgkpiv(), is called when the PIK bit of the PIR register is set. The ASCII keyboard character, vgkbr, is placed in a circular queue, vgkque, and the input character flag, vgkptr, is incremented to the next cell in the queue. A character input flag, vgkflag, is incremented each time a character is input. The routine vggetcar() uses this flag to determine if a character has been input.

Whenever the ASCII character CNTRL P is detected, vgkque is cleared and the flags vgkflag and vgkquefl are reset to zero. This effectively clears the input queue of all previous characters.

C. MANUAL INTERRUPT HANDLER (vgmpiv)

The manual interrupt pivot, vgmpiv(), handles the PIS interrupt from the vector general. The sole action of the interrupt handler is to increment a counter, vgmanint. This counter may be interrogated and cleared by the user.

D. LIGHT PEN INTERRUPT HANDLER (vglpiv)

The light pen interrupt handler, vglpiv(), is responsible for both the light pen interrupt (PIP) and the light

pen sense switch (SP1) interrupts. Each interrupt call to this routine must be processed and cleared before another light pen interrupt may be accepted. For each accepted interrupt the following vector general registers are stored in successive words of valpbuf[]:

Priority interrupt register (PIR)

Instruction register (IR)

Word count (ACR)

X, Y, Z coordinate registers (XR, YR, ZR respectively)

Pen resolution byte (PENR)

Whenever a light pen interrupt occurs and the light pen sense switch is processed, the counter valpsflg is incremented. The user is responsible for the use of this counter.

E. PROCESS TERMINATION ROUTINE (vacrash)

vacrash() is called in response to signal two. The vector general is closed via vaterm() and the process is terminated.

VI. USER INTERFACE ROUTINES

The user interface software has been designed to make the detailed operation of the vector general transparent to the user. However, the user should be familiar with the data structure constructs used to implement the interface.

The basic concept of the user interface software is to define high level constructs which the user interface routines convert into vector general commands. There are three classes of constructs defined: objects, elements, and the picture. An object is the lowest level construct which can be displayed alone. Each object is independently rotatable, scalable, and translatable into any portion of a thirty inch by thirty inch picture space. An object can be as large as fifteen inches by fifteen inches and be rotated or positioned to the extreme limits of the picture space without distortion to any of the remaining visible portion. Each object is composed of one or more independently light pen hookable elements. An element is composed of a series of user drawn images or characters entirely relative to the untransformed image space of its object. An object can be defined unrotated in such a way as to fill the entire object space and then be scaled, rotated, and moved so that the image space is the appropriate size, is viewed from the appropriate aspect, and

is in the appropriate area of the picture. The picture defines the picture scale and screen coordinates for all objects. Figure 5-1 provides a graphic representation of the relationship between each construct.

The user is responsible for the generation and content of each element. Prior to its inclusion within the display list, the user must fill each element with the necessary draw and move commands. In addition, the user must provide three unused words succeeding the draw-move commands. These three words are used by the interface routines to ensure each element is properly terminated. This prevents the vector general from accessing memory outside the display list if the user fails to properly terminate the display list.

The generation and content of all objects and the picture is the responsibility of the interface software. A set of routines are provided to link elements to objects and objects to the picture. Dynamic modification of objects and picture parameters is also provided. However, it is the user's responsibility to dynamically modify the element content.

The following routines are normally transparent to the user and should not be accessed directly by the user.

vgcntrl(addr)
vgcrash()
vgconvt(abp)
vgdpiv()
vgmpiv()
vgobjmod(num,fields,action)
vgoinit()
vgopen()

vgelemod(num,fields,action) vgpicmod(field,action)

vgkpiv() vgpio(bp,mode)

vgmpiv()

The routines that are directly accessable by the user for manipulation and modification of the display data structure are:

vgaddele(app,num,size) vginit()

vgblink(type,num,action) vgiofset(num,val)

vgclock(rate) vgiscal(num,val)

vgcoord(num,x,y,z) vglamps(app)

vgcsr(num,val) vglpen(type,num,action)

vgdelele(num) vgmkobj()

vgdelobj(num) vgpicture()

vgdial(app) vgpost(px,py)

vggetcar() vgpscal(val)

vggetfsw(app) vgrotate(num,x,y,z)

vggetlpn(app) vgterm()

A. SUPPORTING ROUTINES

The function and operation of the routines vgcrash(), vgdpiv(), vgkpiv(), vglpiv(), and vgmpiv() have been discussed earlier. See section IV for a discussion of their function.

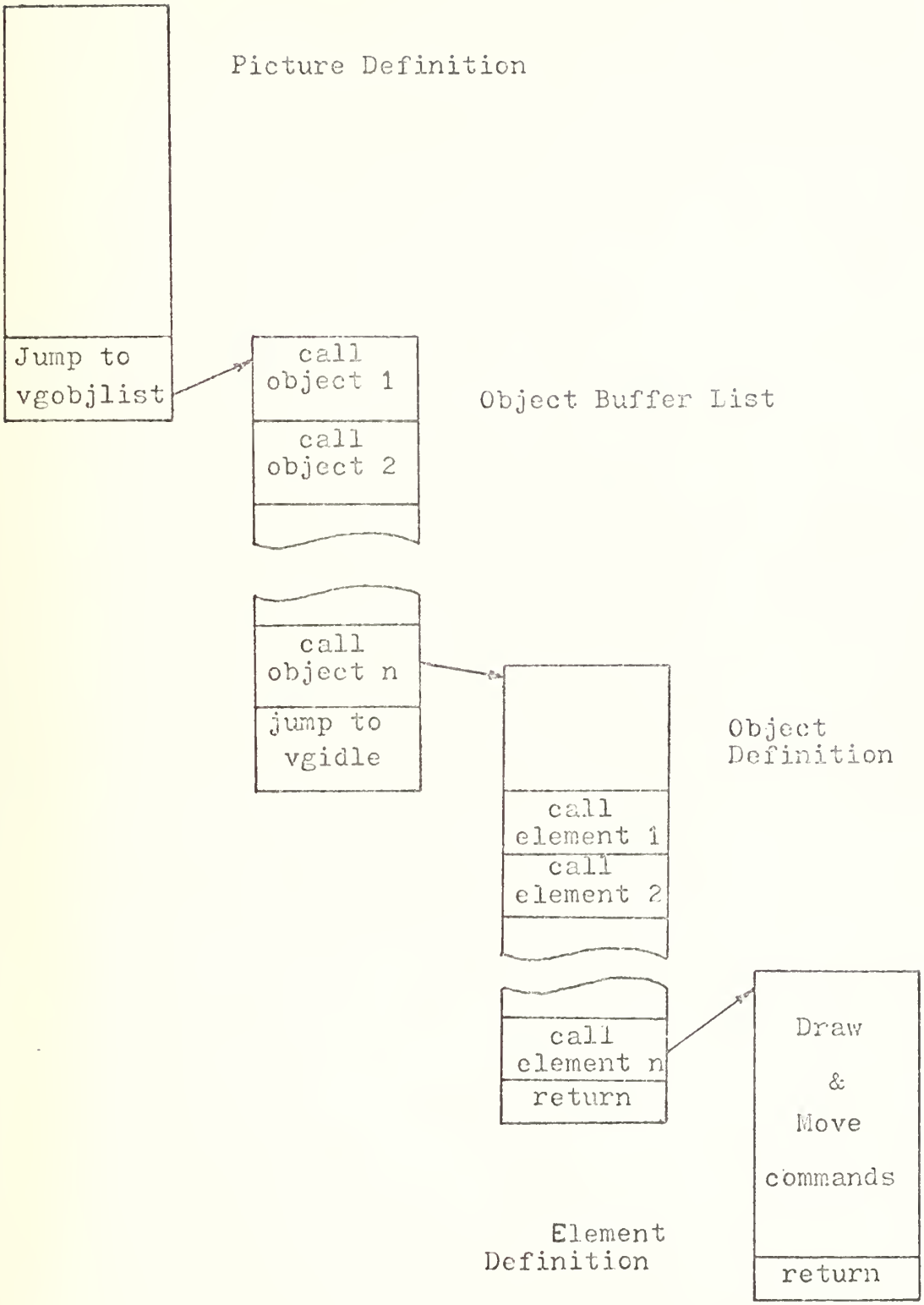


Figure 5-1. Data Structure of the Display Interface.

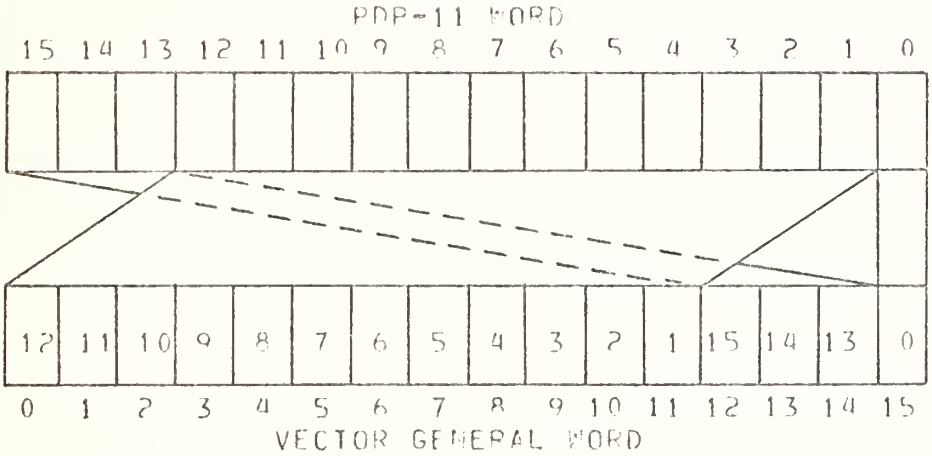
1. Get Real Address Routine (vgcntrl)

Since the vector general uses a DMA channel for display list access, all noncontiguous display lists must be linked by a real PDP-11 address at the point of discontinuity. This routine takes the contents of the input parameter, addr, and converts it to a real PDP-11 address in a format acceptable to the vector general. The address is passed to the system routines by the routine vgpio(). The same routine is called to return the real address in the variable raddr. The returned address is not acceptable to the vector general. The bit manipulation necessary to convert the real address into the vector general memory address register (MAR) format is shown in Figure 5-2.

2. Get User Space Address Routine (vaconvt)

The interface routines maintain no record of the user's element addresses. Therefore, when a display construct is modified, the user space address of the elements involved must be obtained. The MAR format address found in the active display list is converted back to a user space address by this routine. The contents of the parameter abp (a MAR format address), is first converted back to a real PDP-11 address (see Figure 5-2). Since the display process is real-time and locked in memory, the

base address of the process remains constant. A call to vqpio() returns the process block number in the variable base. The block number is then converted to the process base address by multiplying by sixty-four (sixty-four bytes per block). The difference between the process base address and the real PDP-11 address is the user space address offset by the size of the user vector. The user vector is a structure containing all the per process data that does not need to be referenced while the process is swapped. Subtraction of the user vector offset yields the user space address.



The numbers within the vector general word are the bit numbers of the PDP-11 word.

Figure 5-2. PDP-11 to Vector General MAR Format.

3. Modify Element Routine (vgelemod)

The only dynamic system modifications that can be performed on an element is to set or clear the blink mode and light pen hookability.

The element defined by the contents of the parameter, num, is located by a sequential search of elements. The name byte field is compared with the input parameter, num. If a match is found, the value of the field bits are OR'ed or AND'ed into the element depending upon the value of the parameter, action. If action is a zero, the field bits are OR'ed into the element. If action is a one, the complement of the field bits are AND'ed into the element.

The routines possible return codes are:

0 - Normal return

-2 - The element described in the input parameter does not exist

-4 - The value of the element number is non-positive or greater than two hundred fifty-six, the maximum number of elements permitted by the name byte field of the vector general.

The error codes are chosen to be consistent throughout all the interface routines.

4. Modify Object Routine (vaobjmod)

Object modification is more complex than the element modification, because of the number of parameters that may be varied. The structure member, vanum, of each object is compared with the input parameter, num, until a match is found. There is no requirement the object exist in the active display list. If, however, the object is part of the active display, a copy of the object is made into vaworkbuf[]. vaworkbuf[] is then linked to the active display list while the orginal object is modified.

The bit values of the input parameter, fields, determine which parameters are to be modified. The octal number representing the bit position of field and the resulting operation is as follows:

0 - Use the contents of vaf*rot[] as the new values of the rotation matrix.

01 - The value of vaf*csr is taken as the new value of the coordinate scale register.

02 - The values of vaf*dxr, vaf*dyr, and vaf*dzr are assumed to be the current values of the X, Y, and Z coordinates respectively.

010 - The new intensity offset value is obtained from vaf*ior.

020 - vaf*isr is the new value of the intensity scale.

0400 - The light pen halt interruot is set or cleared

depending upon the value of the input parameter, action.

01000 - Display blink for the object is set or cleared as determined by the value of action.

020000 - The light pen interrupt is enabled or disabled depending upon the value of action.

After all modifications have been completed, the modified display list is again linked to the active display list.

The possible return codes are:

0 - Normal return

-1 - The value of the object number parameter is non-positive or greater than NOBJ, the maximum number of objects.

-2 - The object described in the input parameter does not exist.

5. Object Initialization Routine (vaoinit)

This routine is called as part of the program initialization routine, vainit(), to initialize the object structures and link the components of the display list. Since no objects are included at program initialization, only vaidle is linked to the display list. vaidle is a vector general HALT instruction used to keep the vector general from accessing data outside of the defined display lists. Each object is intialized with vector general instructions

permitting the following dynamic modifications:

Change the nine register rotation matrix

Vary the twelve bit X, Y, and Z coordinate displacements

Modify the five bit intensity offset register

Change the twelve bit intensity scale register

Each object is treated as a subroutine of the object buffer list, vaobjlist[]. Therefore, the last executable instruction of each object is a return subroutine jump. Since the initialized object has no elements, the first element of each object is initialized to a load MAR from stack instruction (044016). This instruction causes the vector general to get the next display instruction from vaobjlist[].

6. Open Device Routine (vaopen)

This routine opens all six minor devices and saves the file descriptors for later use by vapio() and vaterm(). The file descriptor variables for the various minor devices are:

vacmd - minor device zero

vadisp - minor device one

vactrl - minor device two

vafnsw - minor device three

vadial - minor device four

vacnvt - minor device five

If a device cannot be opened an error message is printed.

7. Picture Modification Routine (vapicmod)

When the user desires to modify the blink or light pen modes of the picture, this routine performs the modification. If bit nine of the input parameter, field, is set, the blink mode of each element is modified according to the value of the input parameter, action. Bit eight and thirteen of field affect the light pen hookability of the picture.

8. PIO Execution Routine (vapio)

vapio() is called by all routines needing to communicate with the vector general. The input parameter, bp, is the address of the buffer used for the read or write operation. The second parameter, mode, is a coded description of the desired operation. The value and purpose of each mode is as follows:

1 - Read operation using minor device zero (CMD←READ). Used in conjunction with mode 2 to convert a user space address to a real address. The buffer, bp, is a pointer to a receptor for the real address.

2 - Write operation using minor device zero (CMD←WRITE). The address of bp is sent to the system routines for conversion from a user space address to a real address.

3 - Read operation using minor device one (DISP←READ).

This read operation will return the eighty-three vector general register values as stored by the system routines to the eighty-three words beginning at address bp. Normally this mode is used to return the interrupt register value.

5 - Read operation using minor device two (CTRL←READ). Similar to mode three except the current values of the vector general registers (not the dial values) are extracted from the vector general prior to sending them to the caller.

6 - Write operation using minor device two (CTRL←WRITE). The contents of bp, refresh rate, is sent to the system routines to define the refresh reference count.

7 - Read operation using minor device three (FNSW←READ). Similar to mode three except the current values of the function switches are extracted from the vector general prior to the read operation.

8 - Unused

9 - Read operation using minor device four (DIAL←READ). Similar to mode three except the ten dial position values are extracted from the vector general prior to the read operation.

NOTE: The dial positions are analog devices. The conversion from analog to digital requires sixteen microseconds per dial.

10 - Unused

11 - Read operation using minor device five (CNVT+READ). This operation is used with the real to user space address conversion. The buffer pointer, bp, is the receptor for the block number representing the beginning of the real-time process.

12 - Unused

Prior to any read or write operation the value of bp is checked for zero. The caller is prevented from reading or writing using address zero. The read or write operation using address zero can cause the operating system to fail.

B. USER ROUTINES

1. Add Element Routine (vaaddele)

A user defined element is linked to a previously defined object by this routine. The address of the user element buffer is the parameter, abp. The input parameter, size, is the number of bytes in the user's element buffer.

NOTE: The user is required to provide six unused bytes with each element. The six bytes (three words) must succeed the draw-move commands.

The value of size is a byte count so as to follow the convention established for PDP-11 system calls. The byte count must also be even to satisfy the word addressing requirement of the vector general.

If the byte count is even and greater than six, a sequential search of all object structures is initiated. The structure member, vanum, is compared with the input parameter, num. When a match is found, a search of that object's elements is begun. The element search is conducted in increments of seven because seven words of the object structure are required to link each element to the object. The search key is the word having the name byte of the user element. The search is completed when the key word is zero. Before linking the element to the object, the six unused bytes (three words) of the users element buffer are assigned as follows:

Word one - Terminate character mode (024)

Word two - Terminate vector mode (015)

Word three - Load MAR from stack (044016)

The element to be added is always appended to the previously linked elements of the object. Therefore, the word following the new element is set to a load MAR from stack instruction (044016). The seven words linking the element to the object are next assigned as follows:

load NMR (020022)

element number

load MAR (040005)

MCR value (046201)

Store MAR in stack and mark (074216)

Load MAR (040016)

Address of element in MAR format

The value placed in the name byte field (NMR) of the element is returned to the user.

Several conditions could cause an error. The possible error codes and their meanings are as follows:

-1 - The value of the object number parameter is non-positive or greater than NObJ, the maximum number of objects.

-2 - The object described in the input parameter does not exist.

-3 - The number of previously assigned elements equal NELE, the maximum number of elements per object.

-4 - The value of the global variable, elenum, is greater than two hundred fifty-six, the maximum number the vector general name byte register can contain.

-5 - The user element buffer contains less than six bytes or the byte count is odd.

-6 - The user element buffer address is zero.

2. Add Object Routine (voaddobj)

The object referenced by the parameter, num, is to be added to the active display list buffer, vgobjlist[]. The

object to be added is located by sequentially searching the object structure. When the structure member, vgnum, matches the input parameter, num, the desired object has been found. The address of the object is then placed in the variable ptr. Next the end of the active display list is found by multiplying vaobjlist[0] by three. This provides the base for inserting the object. Three words are required to link the object to vaobjlist[]. The base is the last of the three word group. The three word group is assigned as follows:

Store MAR in stack and mark (074216)

Load MAR (040016)

Address of the object in MAR format

The interface routines are designed to ensure that the objects in vaobjlist[] are always compact. Therefore, each object addition is at the end of the previously added objects. Since the last link in vaobjlist[] should always to vaidle, the vaidle link must be reassigned immediately following the newly added object. The instruction sequence affecting this link is:

Load MAR (040016)

Address of vaidle in MAR format

There are four possible return codes for this routine.

0 - Normal return

-1 - The value of the object number parameter is non-

positive or greater than NOBJ, the maximum number of objects.

-2 - The object described in the input parameter does not exist.

-3 - The number of previously defined objects equal NOBJ, the maximum number of objects.

3. Display Blink Routine (vgblink)

The display blink bit, MDB, of the MCR register is set or cleared by this routine. The value of the parameter, type, determines whether the picture, an object, or an element is to be affected. The value of the parameter, action, specifies the clear or set operation. The return codes are the same as those of vgobjmod().

4. Set Refresh Rate Routine (vgclock)

The routine vgclock() is the only routine sending a control parameter to the system routines. The contents of the parameter, rate, (the refresh rate in hertz) is converted into an integer number representing the number of 8.33 millisecond interrupts permitted before refreshing the display. This integer must be between zero and nine. The converted value is sent to the system routines via the routine vgpio().

5. Change Coordinate Routine (vacoord)

The values of the X, Y, and Z coordinate displacements are updated from the input parameters by this routine. The x, y, and z input parameters are placed in vaf.dxr, vaf.dyr, and vaf.dzr respectively. The routine vaobjmod() is then called to update the coordinate displacement values. The object affected by the new values is identified by the input parameter, num.

The range of the X, Y, and Z coordinate displacement values is from negative two thousand forty-eight through two thousand forty-seven. The return codes for this routine are those of vaobjmod(). The return codes for this routine are the same as those of vaobjmod().

6. Change Coordinate Scale Routine (vacsr)

The coordinate scale register of an object is updated by this routine. The lower twelve bits of the parameter, val, is assigned to vaf.csr. vaobjmod() is then called to update the coordinate scale of the object given in the parameter, num. The return codes for this routine are the same as those of vaobjmod().

7. Delete Element Routine (vgdelele)

Since elements are linked to objects by adding the element address to the element field of an object, the deletion process need only delete the address link. The element to be deleted is located in exactly the same manner as in vgmodele(). In this routine, however, only the object containing the element is modified. To prevent unwanted holes within an object, the address of the last element linked to the object is assigned to the location of the element to be deleted. This deletes the desired element but leaves a duplicate copy of the element in the display list. This duplication is eliminated by changing the last active element field to a load MAR from stack instruction (044016).

The return codes for this routine are:

0 - Normal return

-2 - The element described in the input parameter does not exist

-4 - The value of the element parameter is non-positive or greater than two hundred fifty-six, the size of the vector general name byte.

8. Delete Object Routine (vgdelobj)

Deleting an object requires the address link in the object list buffer, vgobjlist[], to be cleared and the

remaining objects links to be compacted.

The object to be deleted is located by sequentially searching the object structures for the object with the structure member, vgnum, matching the input parameter, num. The object list buffer is then searched to determine if the object is currently in the active display list. If the object is currently in the active display list, the address of the last object in vgobjlist[] is copied to the address of the object to be deleted. This last object in vgobjlist[] is then deleted by a load MAR from stack instruction (044016). The structure member, vgnum, is reset to zero making the object available for further use.

The possible return codes for this routine are:

0 - Normal return

-1 - The value of the object number parameter is non-positive or greater than NOBJ, the maximum number of objects.

-2 - The object described in the input parameter does not exist.

9. Get Dial Values Routine (vgdial)

This routine obtains the vector general dial values and returns them to the caller. The twelve bit dial values are returned to the caller in a ten word buffer provided by the caller. The contents of the parameter, abp, is the beginning address of the buffer.

10. Get Character Routine (vagetcar)

The keyboard input flag, vakflag, set by the keyboard interrupt handler, vakbiv(), is checked. If it is zero, a minus one is returned to the caller. If it is non-zero, vakflag is decremented and the value of vakquefl is used as a pointer into the circular keyboard character queue, vakque, to fetch the ASCII character for the caller.

11. Get Function Switch Routine (vagetfsw)

Two vector general register words, vg←fs1 and vg←fs2, are returned to the user beginning at the buffer, abp. Each bit position of the returned words is the value of one function switch. If a bit is set, the function switch has been depressed. The first two rows of the function device are contained in vg←fs1. The last sixteen function switches are retained in vg←fs2.

12. Get Light Pen Interrupt Values Routine (vagetlpn)

The values of the following vector general registers are read sequentially into the buffer abp.

vg←pir - priority interrupt register

vg←ir - instruction register

vg←wcr - word count from start of display

vg←xr - twelve bit X-coordinate displacement

vg_yr - twelve bit Y-coordinate displacement

vg_zr - twelve bit Z-coordinate displacement

vg_penr - one bit pen hit resolution count

13. Display List Initialization (vginit)

The vginit() routine performs all display list initialization and default parameter assignment. The user process is made real-time as part of the call to vgopen(). If vgopen() can not make the process real-time or access all the minor devices, the user process is terminated without further initialization.

After successfully accessing the vector general minor devices, all of the data structure buffers are assigned default values and linked to form a bare bones display system. At this point the display could be run and all interrupts would be processed.

The following default picture parameters are set at display initialization:

All function switches are cleared.

The refresh rate is set to forty hertz.

The frame clock, keyboard, and manual interrupts are enabled.

The display is enabled.

Maximum picture scale is set.

Post X and post Y displacement values are set to zero.

14. Set Intensity Offset Routine (vaiofset)

The input parameter, val, is placed in vgfsior and the object modification routine, vaobjmod(), is called to update the intensity offset register of the object referenced by the input parameter, num. The return codes for this routine are those of vaobjmod().

15. Set Intensity Scale Routine (vaiscal)

The input parameter, val, is placed in vgfsisr and the object modification routine, vaobjmod(), is called to update the intensity scale register of the object referenced by the input parameter, num. The return codes for this routine are those of vaobjmod().

16. Set Function Switch Lamps Routine (valamps)

The four successive words beginning at the buffer address abp are assigned the four vector general function switch registers vasgfs1, vasgfs2, vasgfs3, and vasgfs4.

17. Set Light Pen Enable (valpen)

The light pen hookability of an element or object is set or cleared by this routine. If the input parameter, type, is a zero, the values of the input parameters, num

and action, are passed to the picture modification routine, vapicmod(). If type is a one, the parameters are passed to the object modification routine, vaobjmod(). A type of two will modify the element, num, by calling vaelemod(). The return codes are those of the modification routine called.

18. Make Object Routine (vamkobj)

This routine initializes an object structure for display use. Before the object can be used, it must be initialized to the system default parameters. The default parameters are:

Maximum intensity offset

Constant intensity scale

One-half coordinate scale

Zero for the X, Y, and Z coordinate displacement

Zero rotation

Same interrupts as set by the vainit routine

An unused object is found by searching the object structure until an object is found with a zero assigned as the structure member, vanum. The instructions and default parameters are assigned to the structure and an object number is assigned from the global variable vacurobj. The caller is given the new object number as a return value.

A possible error return code is:

-3 - The number of previously defined objects equal NOBJ, the maximum number of objects.

19. Start Display Routine (vapicture)

The beginning address of the display list, vaseldfsl, is passed to the vector general.

20. Change Post X and Post Y Displacement Routine (varest)

The lower twelve bits of the input parameters, px and py, are assigned to the vector general register vasepdxr and vasepdyr respectively.

21. Change Picture Scale Routine (varscal)

The picture scale is changed to the twelve bit value of the input parameter, val.

22. Rotate Routine (varotate)

The input parameters x, y, and z are the radian measure of the rotation about the X, Y, and Z axis respectively. The necessary calculations to change the nine register rotation matrix are performed here. The final values entered into the rotation matrix represent the trigometric

values corresponding to the requested rotation about each axis. The rotation matrix of the object referenced by the input parameter, num, is updated to reflect the new rotation.

23. Terminate The Display (vdterm)

The vector general is cleared, the minor devices are closed, and the process is made non real-time. This is the final interface call by the user.

APPENDIX A
DATA STRUCTURE FORMATS

Picture Parameter Format

Instruction	Function
0 4 0 0 0 0	Load Lamps
0 0 0 0 0 0	Lamps 0-15
0 0 0 0 0 1	Lamps 16-32, term.
0 4 0 0 2 1	Load Pic Scale
0 7 7 7 6 1	Pic Scale, term.
0 4 0 0 4 7	Load Post Disp.
0 0 0 0 0 0	X Displacement
0 0 0 0 0 1	Y Displacement, term.
0 4 0 0 5 7	Load Lit pen enable
0 0 0 0 0 3	Enable lit pen, term.
0 4 0 0 6 4	Load Lamps
0 0 0 0 0 0	Lamps 16-23
0 0 0 0 0 1	Lamps 24-31, term.
0 4 0 0 1 7	Load Stack Pointer
0 0 0 0 0 1	Stack Address, term.
0 4 0 0 1 6	Load Mem. Addr
0 0 0 0 0 1	Object Buffer Addr, term.

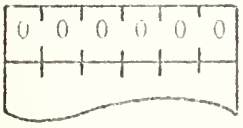
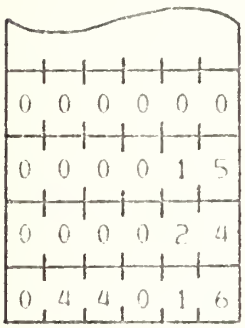
Object Buffer Format

Instruction	Function
0 0 0 0 0 0	Num of objects active
0 7 4 2 1 o	Store MAR in Stack & Mark
0 4 0 0 1 o	Load MAR
0 0 0 0 0 1	Object 1 address, term.
0 7 4 2 1 6	Store MAR in Stack & Mark
0 4 0 0 1 6	Load MAR
0 0 0 0 0 1	Object 2 Address, term.
0 7 4 2 1 6	Store MAR in Stack & Mark
0 4 0 0 1 o	Load MAR
0 0 0 0 0 1	Object n Address, term.
0 4 0 0 1 o	Load MAR
0 0 0 0 0 1	vgiole Address, term.

Object Format

Instruction	Function
0 0 0 0 0 0	Object Number
0 4 0 0 1 4	Load Intensity Offset
0 7 7 7 6 0	Intensity Offset
0 0 0 0 0 1	Intensity Scale, term.
0 4 0 0 2 5	Load Coordinate Scale
0 3 7 7 6 0	Coordinate Scale
0 0 0 0 0 0	X-Coordinate
0 0 0 0 0 0	Y-Coordinate
0 0 0 0 0 0	Z-Coordinate
0 7 7 7 6 0	Rotate X/X
0 0 0 0 0 0	Rotate X/Y
0 0 0 0 0 0	Rotate X/Z
0 0 0 0 0 0	Rotate Y/X
0 7 7 7 6 0	Rotate Y/Y
0 0 0 0 0 0	Rotate Y/Z
0 0 0 0 0 0	Rotate Z/X
0 0 0 0 0 0	Rotate Z/Y
0 7 7 7 6 1	Rotate Z/Z, term.
0 4 0 0 2 2	Load Name Byte
0 0 0 0 0 1	Element Number
0 4 0 0 0 5	Load MCR
0 4 6 2 0 1	Enable bits, term.
0 7 4 2 1 6	Store MAR in Stack & Mark
0 4 0 0 1 6	Load MAR
0 0 0 0 0 1	Element 1 Addr, term.
0 4 0 0 2 2	Load Name Byte
0 0 0 0 0 1	Element Number, term.
0 4 0 0 0 5	Load MCR
0 4 6 2 0 1	Enable bits, term.
0 7 4 2 1 6	Store MAR in Stack & Mark
0 4 0 0 1 6	Load MAR
0 0 0 0 0 1	Element 2 addr, term.
0 4 0 0 1 6	Load MAR
0 0 0 0 0 1	Element n Addr, term.
0 4 4 0 1 6	Load MAR from Stack

Element Format

Instruction	Function
	User Defined Instruction
	User Defined Terminate Inst. Terminate All Vector Modes Terminate Character Mode Load Mar from Stack

APPENDIX B

GLOBAL VARIABLES

All static global variables used through the interface routines are contained in the four files listed here.

vgglob.h

```
 1 int vgkque[NKQUE];                  //  queue holding the last NKQUE
 2                                     //  ASCII keyboard characters
 3
 4 int vgstack[NSTACK];                //  subroutine stack buffer used
 5                                     //  with VG subroutine jumps
 6
 7 int vgworkbuf[VGOBJSIZ];            //  work buffer for sys mods
 8
 9 int vglpbuf[7];                     //  buffer to hold the VG light pen
10                                     //  interrupt registers
11
12 int vgcurobj;                       //  current object number
13
14 int vgidle;
15 char vgkflag;                       //  keyboard character flag.
16                                     //  Incremented when ASCII character
17                                     //  is input
18
19 char vgkptr;                        //  pointer to kque location
20                                     //  receiving the next
21                                     //  keyboard character
22
23 char vgkquefl;                      //  kque pointer to the next character
24                                     //  to be read
25
26 char vgmanint;                      //  manual interrupt counter
27
28 char vglpflag;                      //  light pen flag.  Set when
29                                     //  a light pen interrupt occurs.
30                                     //  Must be cleared by user before
31                                     //  a second interrupt will be
32                                     //  processed
33
34 char vglpsflg;                      //  light pen sense switch flag.
35                                     //  Set when a light pen interrupt
36                                     //  occurs and the sense switch is
37                                     //  depressed.
38
39
40 //  system work buffer used to hold the values to be
41 //  associated with the vector general register commands
42
43 int vgf_pscal;        //  picture scale
44 int vgf_rot[9];       //  rotation matrix
45 int vgf_ior;          //  intensity offset
46 int vgf_isr;          //  intensity scale
47 int vgf_csr;          //  coordinate scale
48 int vgf_dxr;          //  X-coordinate
49 int vgf_dyr;          //  Y-coordinate
50 int vgf_dzr;          //  Z-coordinate
```

vgobj.h

```
int vgelenum;                    //  current element number
int vgobjlist[OLISTSIZ];         //  object list buffer


//  structure of objects that the user has available for
//  display

struct vgobj
    {
    int vgnum;                   //  object number
    int vglior;                  //  load intensity offset
    int vgior;                   //  intensity offset
    int vgisr;                   //  intensity scale, terminate
    int vglcsr;                  //  load coordinate scale
    int vgcsr;                   //  coordinate scale
    int vgx;                     //  X-coordinate
    int vgy;                     //  Y-coordinate
    int vgz;                     //  Z-coordinate
    int vgrot[9];                //  rotation matrix
    int vgele[ELISTSIZ];         //  display element buffer
    int vgnoop;                  //  no op instruction
    } vgobj[NOBJ];
```

vgreg.h

```
#

//  NOTE:   DO NOT ALTER THE ORDER OF THESE VARIABLES

//  The variables in this file correspond to the named
//  vector general registers.  The order is the order in which
//  the values are assigned by the device driver.  The loader
//  assigns these variables sequentially.  Programmatically,
//  these are treated as a vector.


    int vg_fs;                   //  function switch unit 1
    int vg_kbr;                  //  keyboard character
    int vg_tix;                  //  tablet x input
    int vg_tiy;                  //  tablet y input
    int vg_pir;                  //  priority interrupt requests
    int vg_mcr;                  //  mode and control (incl int enables)
    int vg_ir;                   //  display instruction
    int vg_wcr;                  //  word count
    int vg_xr;                   //  X-coordinate
    int vg_yr;                   //  Y-coordinate
    int vg_zr;                   //  Z-coordinate
    int vg_air;                  //  auto-increment
    int vg_ior;                  //  intensity offset (dimming)
    int vg_isr;                  //  intensity scale (cueing)
    int vg_mar;                  //  memory fetch address
    int vg_spr;                  //  stack pointer
    int vg_tgr;                  //  temp. general purpose
    int vg_psr;                  //  picture scale
    int vg_nmr;                  //  name byte
    int vg_csr;                  //  coordinate scale
    int vg_dxr;                  //  coordinate X displacement
    int vg_dyr;                  //  coordinate Y dispalcement
    int vg_dzr;                  //  coordinate Z displacement
    int vg_r11r;                 //  rotation matrix X/X scale
    int vg_r12r;                 //  rotation matrix X/Y scale
    int vg_r13r;                 //  rotation matrix X/Z scale
    int vg_r21r;                 //  rotation matrix Y/X scale
    int vg_r22r;                 //  rotation matrix Y/Y scale
    int vg_r23r;                 //  rotation matrix Y/Z scale
```

```
41      int vg_r31r;                    //  rotation matrix Z/X scale
42      int vg_r32r;                    //  rotation matrix Z/Y scale
43      int vg_r33r;                    //  rotation matrix Z/Z scale
44      int vg_wmcr;                    //  window mode control
45      int vg_xhr;                     //  window boundry X high
46      int vg_xlr;                     //  window boundry X low
47      int vg_yhr;                     //  window boundry Y high
48      int vg_ylr;                     //  window boundry Y low
49      int vg_zhr;                     //  window boundry Z high
50      int vg_zlr;                     //  window boundry Z low
51      int vg_pdxr;                    //  post X displacement
52      int vg_pdyr;                    //  post Y displacement
53      int vg_ccr;                     //  color control
54      int vg_un1;                     //  unused
55      int vg_un2;                     //  unused
56      int vg_un3;                     //  unused
57      int vg_un4;                     //  unused
58      int vg_pirx;                    //  ex dev priority interr requests
59      int vg_mcrx;                    //  ex dev interrupt enables
60      int vg_penr;                    //  pen hit resolution count
61      int vg_un5;                     //  unused
62      int vg_un6;                     //  unused
63      int vg_un7;                     //  unused
64      int vg_fs2;                     //  function switches unit 2
65      int vg_kb2;                     //  keyboard character unit 2
66      int vg_un8;                     //  unused
67      int vg_un9;                     //  unused
68      int vg_fs3;                     //  function switches unit 3
69      int vg_kb3;                     //  keyboard character unit 3
70      int vg_un10;                    //  unused
71      int vg_un11;                    //  unused
72      int vg_fs4;                     //  function switches unit 4
73      int vg_kb4;                     //  keyboard character unit 4
74      int vg_un12;                    //  unused
75      int vg_un13;                    //  unused
76      int vg_pX;                      //  picture X coordinate
77      int vg_pY;                      //  picture Y coordinate
78      int vg_pZ;                      //  picture Z coordinate
79      int vg_jx;                      //  joystick X input
80      int vg_jy;                      //  joystick Y input
81      int vg_jz;                      //  joystick Z input
82      int vg_dial[10];                //  dial inputs
83      int vg_cxr;                     //  window acquisition X coordinate
84      int vg_cyr;                     //  window acquisition Y coordinate
85      int vg_czr;                     //  window acquisition Z coordinate
```

vgsys.h

```
1  #
2  //  NOTE:    DO NOT ALTER THE CONTENTS OF THIS VECTOR!
3
4  //  These variables are the vector general picture initialization
5  //  instructions and data words.  The loader assigns the variables
6  //  sequentially allowing them to be treated as a vector.  The
7  //  order of the variables cannot be changed without affecting
8  //  the operation of the vector general.
9
10
11      int vgs_ldfs1 (040000);         //  load function switch unit 1
12      int vgs_fs1 (0);                //  function switch lamp bits 0-7
13      int vgs_fs2 (01);               //  function switch lamp bits 8-15
14      int vgs_lpsr (040021);          //  load picture scale
15      int vgs_psr (077761);           //  picture scale, terminate
16      int vgs_ldpd (040047);          //  load post diaplacement
17      int vgs_pdxr (0);               //  post X-displacement
18      int vgs_pdyr (01);              //  post Y-displacement, terminate
19      int vgs_xmcr (040057);
20      int vgs_xpir (03);
21      int vgs_lf2 (040064);           //  load function switch unit 2
```

```
22      int vgs_fs3 (0);                //  function switch lamps 0-7
23      int vgs_fs4 (01);               //  function switch lamps 8-15, term.
24      int vgs_lstk (040017);          //  load stack pointer
25      int vgs_stk (0);                //  stack pointer, terminate
26      int vgs_lmar (040016);          //  load memory address register
27      int vgs_mar (0);                //  memory fetch address, term.
```

The file listed here contains the defined constants used through the interface routines.

vgdef.h

```
#

/*************************************************************************
 *  NOTE:   beware of the relation that exists between groups            *
 *          of defines                                                   *
 *************************************************************************/

#define NELE     10                 //  max num of elements per object
#define ELISTSIZ 70                 //  size of element list buffer.
                                    //  This is equal to NELE * 7
#define VCOBJSIZ 89                 //  size of work buffer;
                                    //  must be 19+ELISTSIZ

#define NOBJ     10                 //  max num of objects per picture
#define OLISTSIZ 33                 //  object buffer size.  This is
                                    //  equal to (NOBJ + 1) * 3

#define NSTACK   6                  //  size of subroutine stack

#define NKQUE    6                  //  size of keyboard char queue


//  The following are the read/write defines for I/O

#define CMD_READ 1                  //  read vg commands
#define CMD_WRITE 2                 //  write vg commands
#define DISP_READ 3                 //  read display
#define DISP_WRITE 4                //  write to display
#define CTRL_READ 5                 //  read vg controller
#define CTRL_WRITE 6                //  write vg controller
#define FNSW_READ 7                 //  read function switches
#define FNSW_WRITE 8                //  unused
#define DIAL_READ 9                 //  read dial positions
#define DIAL_WRITE 10               //  unused
#define CNVT_READ 11                //  get user base address
#define KYBD_WRITE 12               //  unused


#define ROT      0                  //  rotation matirx
#define CSR      1                  //  coordinate scale
#define DXYR     2                  //  X,Y,Z coordinates
#define IOR      3                  //  intensity offset
#define ISR      4                  //  intensty scale
#define PSR      5                  //  picture scale
#define POST     6                  //  post X,Y coordinates
#define MPH      8                  //  light pen halt
#define MDB      9                  //  display blink
#define MEP      13                 //  enable light pen interrupt
#define PIP      5                  //  light pen interrupt
#define SPI      0                  //  light pen sense switch
#define PIK      3                  //  keyboard interrupt
#define PIS      2                  //  manual interrupt

#define CLEAR    0                  //  clear flag
#define SET      1                  //  set flag
#define PIC      0                  //  Picture type
#define OBJ      1                  //  object type
#define ELE      2                  //  element type
```

Described here is the system device driver maintained as part of the operating system. The interrupt service routines for the vector general and the service routines for the open() and close() system calls are contained in this routine.

```
 1 #
 2 #include "../param.h"
 3 #include "../conf.h"
 4 #include "../user.h"
 5 #include "../buf.h"
 6 #include "../proc.h"
 7 #include "../seg.h"
 8 #include "../systm.h"
 9
10 #define VG       0                    //  minor device 0
11 #define VGDISP   1                    //  minor device 1
12 #define VGCNTRL  2                    //  minor device 2
13 #define VGFNSW   3                    //  minor device 3
14 #define VGDIAL   4                    //  minor device 4
15 #define VGCONVT  5                    //  minor device 5
16 #define CLOSE    0                    //  restrict access flag
17 #define OPEN     1                    //  permit access flag
18 #define VGADDR   0167770              //  PDP-11 address of VG
19 #define SAR0     0                    //  VG reg command
20 #define SAR1     1                    //  VG reg command
21 #define SAR52    064                  //  VG reg command
22 #define SAR70    0106                 //  VG reg command
23 #define AKC      040000               //  ack. frame clock interrupt
24 #define SCL      01000                //  stop & clear disp controller
25 #define AKWCSD   0176000              //  ack all interpt & reset disp
26 #define BUSY     1
27 #define IDLE     0
28
29 //  four I/O channels in the PDP-11
30
31 struct {
32      int ddo;                         //  direct data output
33      int piox;                        //  extended prog I/O
34      int ma;                          //  memory address
35      int pio;                         //  prog I/O
36      };
37
38 struct buf rvgbuf;
39
40
41 char vglk [0];                        //  minor device 0 lock
42 char displk [0];                      //  minor device 1 lock
43 char ctrllk [0];                      //  minor device 2 lock
44 char fnswlk [0];                      //  minor device 3 lock
45 char diallk [0];                      //  minor device 4 lock
46 char keybdlk [0];                     //  minor device 5 lock
47 char vglock [0];                      //  VG system lock
48 char display;                         //  display active flag
49 char esc [0];                         //  ASCII escape flag
50 int vgbuf[80];                        //  VG register buffer
51 int clockcnt;                         //  frame clock count
52 int clockref [3];                     //  frame clock ref count
53 int base;                            //  proc base address
54 int baddrl;                           //  display base address
55 int baddrx;                           //  extended memory bits
56 int i;
57 int vgaddr;                          //  buffer address
58 int vgcore;                          //  real core address
59 int *vgproc;                         //  pointer to real time process
```

```
60
61
62 vgopen(dev,flag) {
63     switch (dev.d_minor) {
64         case VG: {                          //  channel for virtual to real
65             if (vg1k == OPEN) {             //  address conversion
66                 u.u_error = EIO;
67                 return;
68                 }
69             vg1k = OPEN;
70             break;
71             }
72         case VGDISP: {                      //  channel for display lists
73             if (disp1k == OPEN) {
74                 u.u_error = EIO;
75                 return;
76                 }
77             disp1k = OPEN;
78             break;
79             }
80         case VGCNTRL: {                     //  channel for driver control
81             if (ctrl1k == OPEN) {
82                 u.u_error = EIO;
83                 return;
84                 }
85             ctrl1k = OPEN;
86             break;
87             }
88         case VGFNSW: {                      //  channel to obtain function
89             if (fnsw1k == OPEN) {           //  switches
90                 u.u_error = EIO;
91                 return;
92                 }
93             fnsw1k = OPEN;
94             break;
95             }
96         case VGDIAL: {                      //  channel to obtain dial
97             if (dial1k == OPEN) {           //  positions
98                 u.u_error = EIO;
99                 return;
100            }
101        dial1k = OPEN;
102        break;
103        }
104    case VGCONVT: {                  //  channel for real to virtual
105        if (keybd1k == OPEN) {       //  address conversion
106            u.u_error = EIO;
107            return;
108            }
109        keybd1k = OPEN;
110        break;
111        }
112    default: {
113        u.u_error = EIO;
114        return;
115        }
116    }
117if (disp1k && ctrl1k && fnsw1k && dial1k && keybd1k && vg1k)
118    {
119    vgproc = u.u_procp;
120 // if(srtime(0) != 0)               //  make process real time
121 //     {
122 //     vgclose();
123 //     u.u_error = EACCES;
124 //     return;
125 //     }
126    VGADDR->pio = SCLIAKC;           //  clear & reset VG
127    vglock = OPEN;                   //  enable VG system
128    display = IDLE;
129    }
130)
131
132
133
134 //  The Vector General is a dedicated device.  Therefore,
```

```
135 //  if one minor device is closed access to all minor devices
136 //  is restricted.
137
138 vgclose(dev) {
139     vglk = CLOSE;
140     vglock = CLOSE;
141     displk = CLOSE;
142     ctrllk = CLOSE;
143     fnswlk = CLOSE;
144     diallk = CLOSE;
145     keybdlk = CLOSE;
146     VGADDR->pio = SCL;              //  clear & reset VG
147     nonrtime();                     //  make process non real time
148     }
149
150
151
152
153
154
155 vgstrategy(abp)
156     struct buf *abp; {
157     register struct buf *bp;
158
159     bp = abp;
160     vgcore = bp->b_addr;            //  save real address of buf
161     if(display == IDLE)
162         {
163         base = vgproc->p_addr;      //  save base address for real
164                                     //  to virtual address conversion
165
166         switch(bp->b_xmem)          //  set extended memory bits for VG
167             {
168             case 00:                //  0-32k address block
169                 {
170                 baddrx = 0;
171                 break;
172                 }
173             case 01:                //  32-64k address block
174                 {
175                 baddrx = 024;
176                 break;
177                 }
178             case 10:                //  64-96k address block
179                 {
180                 baddrx = 050;
181                 break;
182                 }
183             case 11:                //  96-128k address block
184                 {
185                 baddrx = 074;
186                 break;
187                 }
188             }
189         }
190     u.u_count = 0;              //  make sys believe I/O complete
191     iodone(bp);
192     }
193
194
195
196
197
198
199 vgwrite(dev,flag) {
200     if (vglock == CLOSE) {
201         u.u_error = EBADF;
202         return;
203         }
204     switch (dev.d_minor) {
205         case VGDISP: {          //  send display list to VG
206             physio(vgstrategy,&rvgbuf,dev,B_WRITE);
207             baddrl = vgcore;
208             if(display == IDLE) {
209                 display = BUSY;
```

```
210                 vgstart();
211                 }
212             return;
213             }
214         case VG: {                  //  save real address
215             physio(vgstrategy,&rvgbuf,dev,B_WRITE);
216             vgaddr = vgcore;
217             return;
218             }
219         case VGCNTRL: {             //  set user refresh rate
220             clockref = cpass();
221             return;
222             }
223         default: {
224             u.u_error = EIO;
225             return;
226             }
227         }
228     }
229
230
231
232
233
234
235
236
237
238
239 vgpassc(abp)                            //  pass data from here to user
240     int abp;                            //  NOTE:   user is responsible
241     {                                   //  for correct byte count
242     char *bp;
243     bp = abp;
244     while(passc(*bp) >= 0) bp++;
245     }
246
247
248
249
250
251
252 vgread(dev,flag) {
253     if (vglock == CLOSE) {
254         u.u_error = EBADF;
255         return;
256         }
257     switch (dev.d_minor) {
258         case VGCNTRL: {                 //  read VG registers
259             VGADDR->pio = SAR0;
260             for (i=0;i<80;i++) vgbuf[i] = VGADDR->pio;
261             break;
262             }
263         case VGFNSW : {             //  read VG function switch registers
264             VGADDR->pio = SAR0;
265             vgbuf[0] = VGADDR->pio;
266             VGADDR->pio = SAR52;
267             vgbuf[52] = VGADDR->pio;
268             break;
269             }
270         case VGDIAL: {              //  read VG dial postions
271             VGADDR->pio = SAR70;
272             for (i=70;i<80;i++)
273                 {
274                 if (i<= 100);   //  waste time
275                 vgbuf[i] = VGADDR->pio;
276                 }
277             break;
278             }
279         case VGDISP: {              //  read last update of VG registers
280             break;
281             }
282         case VGCONVT: {             //  send real basea address to user
283             vgpassc(&base);
284             return;
```

```
285             }
286         case VG: {                  //  send real address to user
287             vgpassc(&vgaddr);
288             return;
289             }
290         default: {
291             u.u_error = E10;
292             return;
293             }
294         }
295     vgpassc(vgbuf);                 //  send VG registers to user
296     return;
297     }
298
299
300
301
302
303
304 vgstart() {
305     clockcnt = 0;
306     VGADDR->piox = baddrx;          //  set VG extended memory bits
307     VGADDR->ma = baddrl;            //  send VG display address
308     VGADDR->pio = AKWCSD;           //  start VG operation
309     }
310
311
312
313 //  VG frame clock interrupt handler.  When enabled frame
314 //  clock interrupts occur every 8.33 msec.
315
316 vgclock() {
317     if(vglock == CLOSE) return;
318     VGADDR->pio = AKC;                  //  ake frame clock intrp
319     if (++clockcnt == clockref) {       //  refresh the display
320         VGADDR->pio = SCL;
321         vgstart();
322         }
323     }
324
325
326
327
328
329 //  The current VG interface software makes no use of the
330 //  P-bit.  However, the P-bit interrupt handler is required
331 //  for system compatibility.
332
333 vgpbit() {
334     }
335
336
337
338
339
340 //  VG device interrupt handler.  Called whenever
341 //  the VG keyboard is depressed, the manual interrupt switch
342 //  is depressed, or a light pen interrupt is detected by
343 //  the VG.
344
345 vgdev()
346     {
347     if (vglock == CLOSE) return;
348     VGADDR->pio = SAR0;             //  get VG interrupt state
349     for(i=0;i<11;i++) vgbuf[i] = VGADDR->pio;
350     VGADDR->pio = SAR52;
351     vgbuf[52] = VGADDR->pio;
352     if(!esc)
353         {
354         if(vgbuf[4]&010 && vgbuf[1] == 012000)
355             {
356             psignal(vgproc,2);          //  terminate the process
357             goto akc;
358             }
359         if(vgbuf[4]&010 && vgbuf[1] == 015400)
```

```
360             {
361             esc++;
362             goto akc;
363             }
364         psignal(vgproc,15);          //  send the user the interrupt
365         }
366     else esc--;
367 akc:
368     VGADDR->pio = vgbuf[4] << 3;         //  ackowledge interrupt
369     }
```

Contained here are the Interface routines grouped by files. The files are in alphabetical order.

vgele.c

```
#include "vgdef.h"
#include "vgglob.h"
#include "vgobj.h"



/*                                                                      *
 *  Add an element to an object.  Possible return codes are:            *
 *          -1  illegal object number                                   *
 *          -2  nonexistant object                                      *
 *          -3  object cannot access more elements                      *
 *          -4  element number is out of range                          *
 *          -5  user display buffer is less than 6 bytes                *
 *          -6  user buffer address is zero                             *
 *      normal return is the element number                             *
 *                                                                      */

vgaddele(abp,num,size)
    int abp;                            //  user element buffer
    int num;                            //  object number
    int size;                           //  num bytes in user buffer
    {
    int i,j;
    int *bp;                            //  buffer pointer

    if((bp=abp) == 0) return(-6);       // check for buf addr of 0
    if(size&01 || (size=>>1)<=3) return(-5);    // check byte count
    if(num<=0) return(-1);      // check object number
/*                                                                      *
 *  Search all the object structures for the object.                    *
 *                                                                      */
    for(i=0;i<NOBJ;i++) if(vgobj[i].vgnum == num) break;
    if(i >= NOBJ) return(-2);               //  object doesn't exist
/*                                                                      *
 *  Find the first empty element location in the object                 *
 *  structure.                                                          *
 *                                                                      */
    for (j=1;j<ELISTSIZ;j =+ 7)
                if (vgobj[i].vgele[j] == 0) break;
    if(j==ELISTSIZ) return(-3);             //  no empty elements

    if((++vgelenum)>256) return(-4);    //  no empty elements
/*                                                                      *
 *  Fill the last 3 words of the element buffer.                        *
 *                                                                      */
    *(bp + (size-1)) = 044016;          //  ld MAR from stack inst
    *(bp +(size-2)) = 024;              //  term char mode
    *(bp +(size-3)) = 015;              //  term all modes exept char
/*                                                                      *
 *  Fill the element words associated with the object.                  *
 *                                                                      */
    vgobj[i].vgele[j+6] = 044016;
    vgobj[i].vgele[j+5] = vgcntrl(bp)|01;
    vgobj[i].vgele[j+4] = 040016;
    vgobj[i].vgele[j+3] = 074216;
    vgobj[i].vgele[j+2] = 046201;
    vgobj[i].vgele[j+1] = 040005;
```

```
59      vgobj[i].vgele[j]   = (vgelenum<<8)|01;
60      vgobj[i].vgele[j-1] = 040022;
61      return(vgelenum);
62      }
63
64
65
66
67
68
69
70
71
72
73  /*                                                                  *
74   *  Delete the element by searching all object structures          *
75   *  for the given element.  Possible return codes are:             *
76   *              0   normal return                                  *
77   *             -2   element does not exist                         *
78   *             -4   element number is out of range                 *
79   *                                                                 */
80
81  vgdelele(num)
82      int num;                        //  element number
83      {
84      int i,j;
85
86      if(num<=0 || num>256) return(-4);   //  check element num
87  /*                                                                  *
88   *  Sequentially search all object structures and elements for the  *
89   *  object containing the element.                                  *
90   *                                                                  */
91      for(i=0;i<NOBJ;i++)
92          {
93          for(j=1;j<ELISTSIZ;j =+ 7)
94              {
95              if(vgobj[i].vgele[j] == 0) break;
96              if (vgobj[i].vgele[j] == ((num<<8)|01)) goto found;
97              }
98          }
99      return(-2);                                 //  element doesn't exist
100 /*                                                                  *
101  *  Delete the element and compact the remaining elements.          *
102  *                                                                  */
103 found:
104     while(vgobj[i].vgele [j+7] != 0)
105         {
106         vgobj[i].vgele[j+6] = vgobj[i].vgele[j+13];
107         vgobj[i].vgele[j+5] = vgobj[i].vgele[j+12];
108         vgobj[i].vgele[j+2] = vgobj[i].vgele[j+9];
109         vgobj[i].vgele[j]   = vgobj[i].vgele[j+7];
110         j =+ 7;
111         }
112     vgobj[i].vgele[j-1] = 044016;
113     vgobj[i].vgele[j] = 0;
114     return(0);
115     }
116
117
118
119
120
121
122
123
124
125
126 /*                                                                  *
127  *  Modify the light pen and display blink fields of the MCR        *
128  *  register of element.  Possible return codes are:                *
129  *              0   normal return                                   *
130  *             -2   element doesn't exist                           *
131  *             -4   element out of range                            *
132  *                                                                 */
133
```

```
134
135 vgelemod(num,field,action)
136     int num;                //  element number
137
138     int field;              //  0400    light pen halt
139                             //  01000   display blink
140                             //  020000  light pen hit detect interrupt
141
142     char action;            //  0 - clear
143                             //  1 - set
144     {
145     int i,j;
146
147     if(num<=0 || num>NELE) return(-4);  //  check element number
148 /*                                                                      *
149  *  Find the object containing the element.                            *
150  *                                                                     */
151
152     for (i=0;i<NOBJ;i++)
153         {
154         for (j=1;j<ELISTSIZ;j =+ 7)
155             {
156             if (vgobj[i].vgele[j] == 0) break;
157             if (vgobj[i].vgele[j] == ((num<<8)|01)) goto found1;
158             }
159         }
160     return(-2);                         // element doesn't exist
161
162 /*                                                                      *
163  *  Modify the light pen and blink control.                            *
164  *                                                                     */
165 found1:
166     if(action == SET)
167         vgobj[i].vgele[j+2] =| field;
168     else if(action == CLEAR)
169         vgobj[i].vgele[j+2] =& ~(field|0100000);
170     return(0);
171     }
```

vginit.c

```
 1 #include "vgdef.h"
 2 #include "vgglob.h"
 3 #include "vgsys.h"
 4 #include "vgobj.h"
 5
 6
 7 extern vgcrash();
 8 extern vgdpiv();
 9
10
11 /*                                                                      *
12  *  The vector general initiallzation routine defines all              *
13  *  system instructions and links all system buffers.                  *
14  *                                                                     *
15  *  If the process can't become real-time or if all minor              *
16  *  devices are unable to be opened the process is terminated.         *
17  *                                                                     */
18
19
20 vginit()
21     {
22
23 /*                                                                      *
24  *  Open all vector general minor devices.                             *
25  *                                                                     */
26
27     if (vgopen() != 0) vgcrash();
28
```

```
29 /*                                                                      *
30  *  Make the process real-time.  This call is placed here              *
31  *  only until the system rtime() call from the driver level           *
32  *  can be debugged.  It should be a call at the driver level          *
33  *  when all minor devices are opened.                                 *
34  *                                                                     */
35
36      if(rtime(0) != 0)
37          {
38          perror("rtime error");
39          vgcrash();
40          }
41
42      signal(2,vgcrash);
43      signal(15,vgdpiv);
44
45      vgclock(40);                        //  set default refresh rate
46
47      vgs_mar  = vgoinit()|01;            //  get address of objlist
48      vgs_stk = vgcntrl(vgstack)|01;      //  stack addr in MAR format
49      vgstack[0] = vgcntrl(&vgidle)|01;   // stack underflow protection
50      vgidle = 036000;                    // halt instruction
51      vglpflag = 0;                       // light pen interrupt flag
52      vglpsflg = 0;                       // light pen sense switch flag
53      vgkflag = 0;                        // keyboard flag
54      vgkptr = 0;                         // keyboard queue pointer
55      vgkquefl = 0;                       // keyboard input flag
56      return;
57      }
58
59
60
61
62
63 /*                                                                      *
64  *  fill buffer with the post X-coordinate and the post                *
65  *  Y-coordinate values.  The values that px and py may assume         *
66  *  are 0177760 (-2048) through 077760 (2047).                         *
67  *                                                                     */
68
69 vgpost(px,py)
70      int px;                             //  post X-coordinate
71      int py;                             //  post Y-coordinate
72      {
73      vgs_pdxr = px << 4;
74      vgs_pdyr = py << 4;
75      }
7
77
78
79
80
81 /*                                                                      *
82  *  Set/Clear the function switch lamps.  Each bit set in the          *
83  *  input buffer will affect one lamp.                                 *
84  *                                                                     */
85
86 vglamps(abp)
87      int abp;                    //  two word buffer pointer
88      {
89      int *bp;
90      if(abp==0) return(-6);
91      bp = abp;
92      vgs_fs1 = *bp & 0177400;
93      vgs_fs2 = ((*bp & 0377) << 8)|01;
94      vgs_fs3 = *(++bp) & 0177400;
95      vgs_fs4 = ((*bp & 0377) << 8)|01;
96      }
97
98
99
100
101
102 /*                                                                      *
103  *  Modify the picture parameters.                                     *
```

```
104  *  The values field can assume are:                                    *
105  *                                                                      */
106
107
108 vgpicmod(field,action)
109      int field;              //  0400    light pen halt
110                              //  01000   display blink
111                              //  020000  light pen hit detect interrupt
112
113      int action;             //  0   clear
114                              //  1   set
115
116      {
117      int i;
118
119      i = 0;
120      while(i<NOBJ) vgobjmod(vgobj[i++].vgnum,field,action);
121      }
122
123
124
125
126
127 /*                                                                      *
128  *  Start the display.                                                  *
129  *                                                                      */
130
131 vgpicture()
132      {
133      vgpio(&vgs_ldfs1,DISP_WRITE);           //  start display
134      }
135
136
137
138
139
140 /*                                                                      *
141  *  Modify the picture scale.  The range of values are 0 - 1.           *
142  *                                                                      */
143
144 vgpscal(val)
145      double val;                         //  picture scale value
146      {
147      int temp;                           //  temp integer value
148      temp = val * 2047;
149      vgs_psr = (temp<<4)|01;
150      return(0);
151      }
```

vgintr.c

```
 1 #include "vgdef.h"
 2 #include "vgglob.h"
 3 #include "vgreg.h"
 4
 5
 6 /*                                                                      *
 7  *  when a light pen interrupt, a sense switch interrupt, a             *
 8  *  keyboard interrupt, or a manual interrupt occurs  the               *
 9  *  VG system interrupt driver passes the interrupt to the              *
10  *  user via this routine.                                              *
11  *                                                                      *
12  *  NOTE:    interrupts are passed via signal 15                        *
13  *                                                                      */
14
15 vgdpiv()
16      {
17      int i;
18
```

```
19      signal(15,vgdpiv);
20      vgpio(&vg_fs,DISP_READ);        //  get interrupt state from VG
21
22      for (i=0;i<7;i++) if((vg_pir>>i)&01) switch(i)
23          {
24
25          case PIP:                   //  light pen interrupt
26
27          case SP1:                   //  light pen sense switch
28              {                       //  interrupt
29              vglpiv();
30              break;
31              }
32
33          case PIK:                   //  keyboard interrupt
34              {
35              vgkpiv();
36              break;
37              }
38
39          case PIS:                   //  manual interrupt
40              {
41              vgmpiv();
42              break;
43              }
44          }
45      return;
46      }
47
48
49
50
51
52  /*                                                                      *
53   *  light pen interrupt handler                                        *
54   *  store the resulting light pen interrupt values in vglpbuf          *
55   *  only if the previous interrupt has been processed by the           *
56   *  user.                                                              *
57   *                                                                     */
58
59  vglpiv()
60      {
61      if((vglpflag==0) && (vg_pir&01))
62          {
63          vglpbuf[0] = vg_pir>>3;         // mode & control reg
64          vglpbuf[1] = vg_ir;             // instruction word reg
65          vglpbuf[2] = vg_wcr;            // word count reg
66          vglpbuf[3] = vg_xr>>4;          // X-coordinate
67          vglpbuf[4] = vg_yr>>4;          // Y-coordinate
68          vglpbuf[5] = vg_zr>>4;          // Z-coordinate
69          vglpbuf[6] = vg_penr;           // pen resolution byte
70          vglpflag++;
71          }
72      if (vg_pir&01) vglpsflg++;
73      }
74
75
76
77
78
79  /*                                                                      *
80   *  Vector General Keyboard Character Pivot                            *
81   *  when a keyboard character interrupt has occured, this routine      *
82   *  gets the keyboard character from the Vector General                *
83   *  places it in vgkque, and increments the character flag,            *
84   *  vgkflag, to indicate a character has been input                    *
85   *                                                                     *
86   *  NOTE:   The user should empty the queue by calling                 *
87   *  vggetcar().                                                        *
88   *                                                                     */
89
90  vgkpiv() {
91      vgkflag++;
92      if (vg_kbr == 010000)
93          {
```

```
94          vgkflag = 0;
95          vgkptr = 0;
96          vgkquefl = 0;
97          return;
98          }
99      if (vgkptr == NKQUE) vgkptr = 0;
100      vgkque[vgkptr++] = vg_kbr;
101      }
102
103
104
105
106 /*                                                                    *
107  *  Vector General Manual Interrupt Pivot.                            *
108  *  when a manual switch interrupt occurs, this routine increments    *
109  *  the manual interrupt counter                                      *
110  *                                                                    */
111
112 vgmpiv() {
113      vgmanint++;
114      }
115
116
117
118
119
120
121
122 /*                                                                    *
123  *  kill the process.                                                 *
124  *  called when a condition requires process termination              *
125  *  i.e. "rubout" on the DATAMEDIA terminal or CTRL T                 *
126  *  on the vector general keyboard                                    *
127  *                                                                    */
128
129 vgcrash() {
130      vgterm();
131      exit();
132      }
```

vgobj.c

```
1 #include "vgdef.h"
2 #include "vgglob.h"
3 #include "vgobj.h"
4
5
6
7
8 /*                                                                    *
9  *  Add the object to the active display list.                        *
10 *  The possible return values are:                                   *
11 *          0   normal termination                                    *
12 *          -1  object number is neg., zero, or greater than NOBJ     *
13 *          -2  object doesn't exist                                  *
14 *          -3  object list is full                                   *
15 *                                                                    */
16
17 vgaddobj(num)
18      int num;                        //  object number
19      {
20      int *addr;                      //  object address
21      int i,j;
22
23      if(num<=0) return(-1);  //  check object number
24      if(vgobjlist[0]>NOBJ) return(-3);   //  object list full
25 /*                                                                    *
26  *  Find the object structure with the desired object number          *
27  *                                                                    */
```

```
28      for(i=0;i<NOBJ;i++) if(vgobj[i].vgnum == num) break;
29      if(i>=NOBJ) return(-2);                 //  object doesn't exist
30
31      j = vgobjlist[0] *3;
32      vgobjlist[j+2] = vgcntrl(&vgidle)|01;
33      vgobjlist[j+1] = 040016;                //  load MAR
34      vgobjlist[j]   = vgcntrl(&vgobj[i].vgnum)|01;
35      vgobjlist[j-1] = 040016;                //  load MAR
36      vgobjlist[j-2] = 074216;                //  store MAR in stack & mark
37      vgobjlist[0]++;
38      return(0);
39      }
40
41
42
43
44
45
46
47
48
49
50  /*                                                                      *
51   *  Find the object, delete it, and if in the active display list      *
52   *  compact the resulting active display list.  Possible return        *
53   *  values are:                                                        *
54   *          0   normal return                                          *
55   *          -1  object number out of range                             *
56   *          -2  object doesn't exist                                   *
57   *                                                                     */
58
59  vgdelobj(num)
60      int num;                            //  object number
61      {
62      int addr;                           //  address pointer
63      int i,j,k;
64
65      if(num<=0) return(-1);  //  check object number
66  /*                                                                      *
67   *  Sequentially search the object structures until the desired        *
68   *  object can be found.                                               *
69   *                                                                     */
70      for(i=0;i<NOBJ;i++) if(vgobj[i].vgnum==num) break;
71      if(i>=NOBJ) return(-2);                 //  object doesn't exist
72      vgobj[i].vgnum = 0;                     //  delete the object
73  /*                                                                      *
74   *  Check if the object is in the active display list.  If yes         *
75   *  the link in vgobjlist must be removed.  If no then only the        *
76   *  object number must be zeroed.                                      *
77   *                                                                     */
78      addr = vgcntrl(&vgobj[i].vgnum)|01;
79      for(j=1;j<vgobjlist[0];j++) if(vgobjlist[j*3]==addr) break;
80  /*                                                                      *
81   *  Compact the resulting display list.                                *
82   *                                                                     */
83      if(j<vgobjlist[0])
84          {
85          vgobjlist[0]--;
86          vgobjlist[j*3] = vgobjlist[vgobjlist[0]*3];
87          vgobjlist[vgobjlist[0]*3] = vgcntrl(&vgidle)|01;
88          }
89      return(0);
90      }
91
92
93
94
95
96
97
98
99
100
101 /*                                                                      *
102  *  Find an unused object structure and initialize the structure       *
```

```
103  *  to all default parameters.  Possible return codes are:          *
104  *          -3  all objects previously defined                      *
105  *  Normal return is the object number assigned to the new object   *
106  *                                                                  */
107
108 vgmkobj()
109     {
110     int i;
111 /*                                                                  *
112  *  Find the first unused object structure.                         *
113  *                                                                  */
114     for(i=0;i<NOBJ;i++) if(vgobj[i].vgnum==0) break;
115     if(i>=NOBJ) return(-3);      //  all object in use
116     vgobj[i].vgnum = ++vgcurobj;
117     vgobj[i].vgior = 077760;          //  intensity offset
118     vgobj[i].vgisr = 01;              //  intensity scale, terminate
119     vgobj[i].vgcsr = 037760;          //  coordinate scale
120     vgobj[i].vgx   = 0000000;         //  X-coordinate
121     vgobj[i].vgy   = 0000000;         //  Y-coordinate
122     vgobj[i].vgz   = 0;               //  Z-coordinate
123     vgobj[i].vgrot[0] = 077760;       //  fill rotation matrix
124     vgobj[i].vgrot[4] = 077760;
125     vgobj[i].vgrot[8] = 077761;       //  terminate
126     return(vgobj[i].vgnum);
127     }
128
129
130
131
132
133
134
135
136
137
138 /*                                                                  *
139  *  Modify the object as indicated by the input parameter.          *
140  *  Possible return codes are:                                      *
141  *          0   normal return                                       *
142  *          -1  object number out of range                          *
143  *          -2  object doesn't exist                                *
144  *                                                                  */
145
146 vgobjmod(num,fields,action)
147     int num;                     //  object number
148
149     int fields;                  //  0 - rotation matrix
150                                  //  1 - coordinate scale
151                                  //  2 - X,Y,Z coordinates
152                                  //  3 - intensity offset
153                                  //  4 - intensity scale
154                                  //  8 - light pen halt
155                                  //  9 - display blink
156                                  //  13 - light pen interrupt
157
158     char action;                 //  0 - clear
159                                  //  1 - set
160     {
161     int ptr;                     //  pointer to object to be modified
162     int obj;                     //  ptr. to obj. in obj. buf. list
163     int i,j;
164     int taddr;                   //  temp MAR addr of object
165     int *addr;                   //  address of an object
166     char active;                 //  object in active display list
167
168     if(num <= 0) return(-1);          // check object number
169 /*                                                                  *
170  *  Sequentially search the object structures for the desired       *
171  *  object.                                                         *
172  *                                                                  */
173     for(ptr=0;ptr<NOBJ;ptr++) if(vgobj[ptr].vgnum == num) break;
174     if(ptr>=NOBJ) return(-2);                 //  object does not exist
175 /*                                                                  *
176  *  Check the active display list for the object to be modified.    *
177  *                                                                  */
```

```
178     addr = &vgobj[ptr].vgnum;
179     taddr = vgcntrl(addr)|01;
180     for(obj=1;obj<vgobjlist[0];obj++)if(vgobjlist[obj*3]==taddr)break;
181 /*                                                                    *
182  *  Make a copy of the object and link the copy to the active        *
183  *  display list.                                                    *
184  *                                                                   */
185     active = 0;
186     if (obj < vgobjlist[0])
187         {
188         for(i=0;i<VGOBJSIZ;i++) vgworkbuf[i] = *(addr++);
189         taddr = vgobjlist[obj*3];    //  save MAR addr of the org. obj
190         vgobjlist[obj*3] = vgcntrl(vgworkbuf)|01;
191         active++;                    //  set object active flag
192         }
193 /*                                                                    *
194  *  Make the modifications to the orginal object.                    *
195  *                                                                   */
196     for(i=0;i<16;i++)
197         {
198         if ((fields>>i)&01) switch(i)
199             {
200             case ROT:                          //  rotation matrix
201                 {
202                 for(j=0;j<9;j++) vgobj[ptr].vgrot[j]=vgf_rot[j]<<4;
203                 vgobj[ptr].vgrot[8] =| 01;
204                 break;
205                 }
206             case CSR:                          //  coordinate scale
207                 {
208                 vgobj[ptr].vgcsr = vgf_csr<<4;
209                 break;
210                 }
211             case DXYR:                         //  X,Y,Z coordinates
212                 {
213                 vgobj[ptr].vgx = vgf_dxr<<4;
214                 vgobj[ptr].vgy = vgf_dyr<<4;
215                 vgobj[ptr].vgz = vgf_dzr<<4;
216                 break;
217                 }
218             case IOR:                          //  intensity offset
219                 {
220                 vgobj[ptr].vgior = vgf_ior<<4;
221                 break;
222                 }
223             case ISR:                          //  intensity scale
224                 {
225                 vgobj[ptr].vgisr = (vgf_isr<<4)|01;
226                 break;
227                 }
228             case MPH:                          //  light pen halt
229             case MDB:                          //  display blink
230             case MEP:                          //  enable light pen
231                 {
232                 if(action==SET)
233                     for (j=1;j<ELISTSIZ;j=+ 7)
234                         {
235                         if(vgobj[ptr].vgele[j]==0) break;
236                         vgobj[ptr].vgele[j+2] =| 1<<i;
237                         }
238                 if(action == CLEAR)
239                     for(j=1;j<ELISTSIZ;j=+ 7)
240                         {
241                         if(vgobj[ptr].vgele[j]==0) break;
242                         vgobj[ptr].vgele[j+2]=& ~((1<<i)|0100000);
243                         }
244                 break;
245                 }
246             default:
247                 {
248                 break;
249                 }
250             }
251         }
252     if (active) vgobjlist[obj*3] = taddr;
```

```
253     return(0);
254     }
255
256
257
258
259
260
261
262
263
264
265 /*
266  *  initiate the object buffer list and fill all constant                *
267  *  fields.                                                              *
268  *                                                                       */
269
270 vgoinit()
271     {
272     int i;
273     int J;
274
275     J = 1;
276     vgcurobj = 0;
277     vgelcnum = 0;
278
279 /*
280  *  Initialize the object list buffer                                    *
281  *                                                                       */
282
283     vgobjlist[0] = 1;                   // set first object number
284     vgobjlist[1] = 030000;              //  halt
285
286 /*
287  *  Initialize each object structure                                     *
288  *                                                                       */
289
290     for(i=0;i<NOBJ;i++)
291         {
292         vgobj[i].vglior  = 040014;      // load intensity offset reg
293         vgobj[i].vglcsr  = 040023;      // load coordinate scale reg
294         vgobj[i].vgele[0]= 044016;      // load MAR from stack
295         }
296     return(vgcntrl(vgobjlist));
297     }
```

vgpio.c

```
 1 #include "vgdef.h"
 2
 3     int vgctrl;              //  controller file descriptor
 4     int vgdials;             //  dials file descriptor
 5     int vgdisp;              //  display file descriptor
 6     int vgfnsw;              //  function switch file descriptor
 7     int vgcnvt;              //  keyboard file descriptor
 8     int vgcmd;               //  command file discriptor
 9
10 /*                                                                       *
11  *  Convert the display list address into a user space address           *
12  *                                                                       */
13
14 vgconvt(abp)
15     int abp;                 //  display list address pointer
16     {
17     int bp;
18     int base;                //  base block number of process
19     int page;                //  most sig 3 bits of address
20     int virtual;             //  user space address
21
```

```
22 /*                                                                      *
23  *  Convert the display list address into a real address               **
24  *                                                                     */
25
26      page = (abp & 016) << 12;
27      abp = (abp>>3) & 017776;
28      bp = abp | page;
29
30 /*                                                                      *
31  *  Get the base block number of the process                           **
32  *                                                                     */
33
34      vgpio(&base,CNVT_READ);
35
36 /*                                                                      *
37  *  Convert the block number into an address and convert the real      **
38  *  address into a user space address.                                 **
39  *                                                                     */
40
41      virtual = (bp - (base<<06)) - 02000;
42      return(virtual);
43      }
44
45
46
47
48
49 /*                                                                      *
50  *  Convert the user space address into a real address in MAR          **
51  *  format.                                                            **
52  *                                                                     */
53
54 vgcntrl(addr)
55      int addr;                   //  user space address pointer
56      {
57      int *laddr;                 //  logical address
58      int raddr;                  //  real address
59      int mar;                    //  VG memory address register
60      laddr = addr;
61
62 /*                                                                      *
63  *  Get the real address of the user space address                     **
64  *                                                                     */
65
66      vgpio(laddr,CMD_WRITE);
67      vgpio(&raddr,CMD_READ);
68
69 /*                                                                      *
70  *  Convert the real address into MAR format.                          **
71  *                                                                     */
72
73      mar = (raddr) >> 12;
74      mar =& 016;
75      mar =| (raddr<<3);
76      return(mar);
77      }
78
79
80
81
82
83 /*                                                                      *
84  *  Open each of the minor devices and retain the file                 **
85  *  descriptors. The minor device number and the file descriptor       **
86  *  associated with it is:                                             **
87  *          0   vgcmd       /dev/vg                                    **
88  *          1   vgdisp      /dev/vgdp                                  **
89  *          2   vgcntrl     /dev/vgct                                  **
90  *          3   vgfnsw      /dev/vgfs                                  **
91  *          4   vgdials     /dev/vgdl                                  **
92  *          5   vgenvt      /dev/vgkb                                  **
93  *                                                                     */
94
95 vgopen()
96      {
```

```
97      if ((vgcmd = open("/dev/vg",2)) < 0)          // minor device 0
98          {
99          perror("open vgcmd error");
100         return(-7);
101         }
102     if ((vgdisp = open("/dev/vgdp",2)) < 0)       // minor device 1
103         {
104         perror("open vgdisp error");
105         return(-2);
106         }
107     if ((vgctrl = open("/dev/vgct",2)) < 0)       // minor device 2
108         {
109         perror("open vgctrl error");
110         return(-3);
111         }
112     if ((vgfnsw = open("/dev/vgfs",0)) < 0)       // minor device 3
113         {
114         perror("open vgfnsw error");
115         return(-4);
116         }
117     if ((vgdials = open("/dev/vgdl",0)) < 0)      // minor device 4
118         {
119         perror("open vgdials error");
120         return(-5);
121         }
122     if ((vgcnvt = open("/dev/vgkb",0)) < 0)       // minor device 5
123         {
124         perror("open vgcnvt error");
125         return(-6);
126         }
127     return(0);
128     }
129
130
131
132
133
134/*                                                                    *
135 *  Vector General Read/Write Routine                                 *
136 *  all communication with the vector general is handled via this     *
137 *  routine.  The mode determines the action to be taken.             *
138 *  The acceptable values for the mode are:                           *
139 *          1 - read using minor device 0                             *
140 *          2 - write using minor device 0                            *
141 *          3 - read using minor device 1                             *
142 *          4 - write using minor device 1                            *
143 *          5 - read using minor device 2                             *
144 *          6 - write using minor device 2                            *
145 *          7 - read using minor device 3                             *
146 *          8 - write using minor device 3                            *
147 *          9 - read using minor device 4                             *
148 *          10 - write using minor device 4                           *
149 *          11 - read using minor device 5                            *
150 *          12 - write using minor device 5                           *
151 *  Return of -1 is the result of an addressing error.                *
152 *                                                                    */
153
154vgpio(bp,mode)
155     int bp;                          //  buffer address pointer
156     int mode;                        // type I/O operation
157     {
158     int *abp;
159
160/*                                                                    *
161 *  Check buffer address.  Do not perform the operation is the        *
162 *  address is zero.                                                  *
163 *                                                                    */
164
165     if(bp == 0) vgcrash();
166
167     abp = bp;
168     switch (mode)
169         {
170         case CMD_READ:                   //  calc abs address
171             {
```

```
172             if(read(vgcmd,abp,2) < 0)
173                 perror("CMD_READ error");
174             break;
175             }
176
177         case CMD_WRITE:                 //  get abs address
178             {
179             if(write(vgcmd,abp,2) < 0)
180                 perror("CMD_WRITE error");
181             break;
182             }
183
184         case DISP_READ:                 //  get interrupt registers
185             {
186             if(read (vgdisp,abp,166) < 0)
187                 perror("DISP_READ error");
188             break;
189             }
190
191         case DISP_WRITE:                //  sent display list
192             {
193             if(write(vgdisp,abp,10) < 0)
194                 perror("DISP_WRITE error");
195             break;
196             }
197
198         case CTRL_READ:                 //  get current vg register value
199             {
200             if(read (vgctrl,abp,2) < 0)
201                 perror("CTRL_READ error");
202             break;
203             }
204
205         case CTRL_WRITE:                //  sent system control words
206             {
207             if(write(vgctrl,abp,2) < 0)
208                 perror("CTRL_WRITE error");
209             break;
210             }
211
212         case FNSW_READ:                 //  get func switch value
213             {
214             if(read (vgfnsw,abp,166) < 0)
215                 perror("FNSW_READ error");
216             break;
217             }
218
219         case FNSW_WRITE:                //  not used
220             {
221             break;
222             }
223
224         case DIAL_READ:                 //  get dial positions
225             {
226             if(read(vgdials,abp,166) < 0)
227                 perror("DIAL_READ error");
228             break;
229             }
230
231         case DIAL_WRITE:                //  unused
232             {
233             break;
234             }
235
236         case CNVT_READ:                 //  get base address
237             {
238             if(read(vgcnvt,abp,2) < 0)
239                 perror("CNVT_READ error");
240             break;
241             }
242
243         case KYBD_WRITE:                //  unused
244             {
245             break;
246             }
```

```
247         default:
248             {
249             break;
250             }
251         }
252     }
253
254
255
256
257
258/*                                                                      *
259 *  Terminate vector general operations.  Close all minor devices      *
260 *  and make the process non real-time.                                *
261 *                                                                     */
262
263vgterm()
264     {
265     if(close(vgdisp) < 0)
266         perror("Close error");
267     }
```

vgrdwri.c

```
 1 #include "vgdef.h"
 2 #include "vgreg.h"
 3 #include "vgglob.h"
 4
 5
 6 /*                                                                     *
 7  *  Get the ten vector general dial values.                            *
 8  *                                                                     */
 9
10 vgdial(abp)
11     int abp;                          //  ten word buffer pointer
12     {
13     int *bp;
14     int i;
15     if(abp==0) return(-6);
16     bp = abp;
17     vgpio(&vg_fs,DIAL_READ);          //  get dial values from VG
18     for(i=0;i<10;i++) *(bp++) = vg_dial[i]>>4;
19     }
20
21
22
23
24
25 /*                                                                     *
26  *  get function switch values                                         *
27  *  the thirty-two values of the VG function switches                  *
28  *  are returned to the user via the two word buffer.                  *
29  *  A bit that is set corresponds to a VG function switch              *
30  *  that has been depressed.                                           *
31  *                                                                     */
32
33 vggetfsw(abp)
34     int abp;                                  //  2 word buffer
35     {
36     int *bp;
37     if(abp==0) return(-6);
38     bp = abp;
39     vgpio(&vg_fs,FNSW_READ);          // get function switch values
40     *(bp++) = vg_fs;
41     *bp = vg_fs2;
42     }
43
44
45
```

```
46
47
48 /*                                                                    *
49  *  Calculate the refresh rate and sent the value to the vector       *
50  *  general.  The value sent must be an integer between 0 and 9       *
51  *                                                                    */
52
53 vgelock(rate)
54     int rate;                              //  refresh rate in hertz
55     {
56     rate = 120/rate;
57     vgpio(&rate,CTRL_WRITE);
58     }
```

vgusr.e

```
 1 #include "vgdef.h"
 2 #include "vgglob.h"
 3 #include "vgreg.h"
 4
 5 /*                                                                    *
 6  *  character read routine                                            *
 7  *  Returns the oldest keyboard character in the character queue.     *
 8  *  If no character has been input return -1.                         *
 9  *                                                                    *
10  *  NOTE:   The character is filled by a keyboard                     *
11  *  character interrupt causing vgkpiv() to be called.                *
12  *                                                                    */
13
14 vggetcar()
15     {
16     if(vgkflag == 0) return(-1);
17     vgkflag--;                             // removed one character
18     if(vgkquef1 == NKQUE) vgkquef1 = 0;
19     return(vgkque[vgkquef1++]>>8);
20     }
21
22
23
24
25
26 /*                                                                    *
27  *  Set/clear the blink mode on the picture, object, or element.      *
28  *                                                                    */
29
30 vgblink(type,num,action)
31     char type;                 //  0 - picture
32                                //  1 - object
33                                //  2 - element
34
35     int num;                   //  0 - picture
36                                //  object or element num
37
38     char action;               //  0 - clear
39                                //  1 - set
40     {
41
42     switch(type)
43         {
44         case PIC:              //  SET/CLEAR blink picture
45             {
46             return(vgpicmod(01000,action));
47             }
48         case OBJ:              //  SET/CLEAR blink on object 'num'
49             {
50             return(vgobjmod(num,01000,action));
51             }
52         case ELE:              //  SET/CLEAR blink on element 'num'
53             {
```

```
54              return(vgelemod(num,01000,action));
55              }
56          }
57      }
58
59
60
61
62
63 /*                                                                      *
64  *  Modify the rotation matrix of the object.  The return values       *
65  *  are those of the object modification routine.                      *
66  *                                                                     */
67
68 vgrotate(num,x,y,z)
69      int num;                        //  object number
70      double x;                       //  radian rotation about X-axis
71      double y;                       //  radian rotation about Y-axis
72      double z;                       //  radian rotation about Z-axis
73      {
74      double sin();
75      double cos();
76      double sinx,siny,sinz,cosx,cosy,cosz;
77      sinx = sin(x);
78      siny = sin(y);
79      sinz = sin(z);
80      cosx = cos(x);
81      cosy = cos(y);
82      cosz = cos(z);
83      vgf_rot[0] = (cosz*cosy - sinx*siny*sinz)*2047;
84      vgf_rot[1] = (cosy*sinz + sinx*siny*cosz)*2047;
85      vgf_rot[2] = -siny*cosx*2047;
86      vgf_rot[3] = -sinz*cosx*2047;
87      vgf_rot[4] = cosx*cosz*2047;
88      vgf_rot[5] = sinx*2047;
89      vgf_rot[6] = (siny*cosz + sinx*cosy*sinz)*2047;
90      vgf_rot[7] = (siny*sinz - sinx*cosy*cosz)*2047;
91      vgf_rot[8] = cosx*cosy*2047;
92      return(vgobjmod(num,01));
93      }
94
95
96
97
98
99 /*                                                                      *
100  *  Modify the X, Y, and Z coordinates of the object.  The range       *
101  *  of values are from -2048 (0177777) through 2047 (07777).           *
102  *  The return codes are those of the object modification routine.     *
103  *                                                                     */
104
105 vgcoord(num,x,y,z)
106     int num;                    //  object number
107     int x;                      //  X coordinate
108     int y;                      //  Y coordinate
109     int z;                      //  Z coordinate
110     {
111     vgf_dxr = x;
112     vgf_dyr = y;
113     vgf_dzr = z;
114     return(vgobjmod(num,04));
115     }
116
117
118
119
120
121 /*                                                                      *
122  *  Modify the intensity offset of the object.  The range of values    *
123  *  is from 0 to 1.  The return codes are those of the object          *
124  *  modification routine.                                              *
125  *                                                                     */
126
127 vgiofset(num,val)
128     int num;                    //  object number
```

```
129     double val;             //  intensity offset value
130     {
131     vgf_ior = val*2047;
132     return(vgobjmod(num,010));
133     }
134
135
136
137
138
139 /*                                                                      *
140  *  Modify the intensity scale of the object.  The range of values     *
141  *  is from 0 to 1.  The return codes are those of the object          *
142  *  modification routine.                                              *
143  *                                                                     */
144
145 vgiscal(num,val)
146     int num;                                    //  object number
147     double val;                                 //  intensity scale
148     {
149     vgf_isr = val*2047;
150     return(vgobjmod(num,020));
151     }
152
153
154
155
156
157 /*                                                                      *
158  *  Modify the coordinate scale of the object.  The range of values    *
159  *  are 0 to 1.  The return codes are those of the object              *
160  *  modification routine.                                              *
161  *                                                                     */
162
163 vgcsr(num,val)
164     int num;                        //  object number
165     double val;                     //  coordinate scale value
166     {
167     vgf_csr = val*2047;
168     return(vgobjmod(num,02));
169     }
170
171
172
173
174                                                     .       .
175 /*                                                                      *
176  *  Set/clear the light pen hookability of the object or element       *
177  *  The light pen halt, light pen interrupt, and light pen sense       *
178  *  switch are all treated as a single unit to be set/cleared.         *
179  *  Return codes are those of the modification routine concerned.      *
180  *                                                                     */
181
182 vglpen(type,num,action)
183     char type;                  //  1 - object
184                                 //  2 - element
185
186     int num;                    //  object or element number
187
188     char action;                //  0 - clear
189                                 //  1 - set
190     {
191     switch(type)
192         {
193         case OBJ:                       // set/clear object
194             {
195             return(vgobjmod(num,020400,action));
196             }
197         case ELE:                       // set/clear element
198             {
199             return(vgelemod(num,020400,action));
200             }
201         }
202     return(0);
203     }
```

```
204
205
206
207
208
209 /*                                                                      *
210  *  Get the light pen interrupt registers.  The light pen               *
211  *  interrupt flag is cleared so another light pen interrupt may        *
212  *  be accepted by the light pen interrupt handler.                     *
213  *                                                                      */
214
215 vggetlpn(abp)
216     int abp;                            //  8 word buffer pointer
217     {
218     int *bp;
219     int i;
220     bp = abp;
221     for(i=0;i<7;i++)
222         *(bp++) = vglpbuf[i];
223     vglpflag = 0;
224     }
```

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